SYSTECH WATER RESOURCES, INC.

ENVIRONMENTAL ENGINEERING AND
WATER RESOURCES SYSTEMS ANALYSIS

Inclusion of Zooplankton Population Dynamics in the Link-Node Model

Report 5.6.1

CALIFORNIA DEPARTMENT OF FISH AND GAME
GRANT AGREEMENT E0883006

Prepared by

Scott Sheeder and Joel Herr

Systech Water Resources, Inc.
1200 Mount Diablo Blvd, Suite 102
Walnut Creek, CA 94596
(925) 355-1780

In Cooperation with

Ecological Engineering Research Program
School of Engineering & Computer Sciences
University of the Pacific,
3601 Pacific Avenue, Chambers Technology Center
Stockton, CA 95211

November, 2013

Introduction

Zooplankton are small floating or weakly swimming animals that along with phytoplankton, make up the planktonic food supply that serves as the foundation of the oceanic food web. The group primarily consists of microscopic organisms that include protozoans, copepods, and krill which are important components of the food web in the lower San Joaquin River. Zooplankton feed primarily on phytoplankton, which consume oxygen through respiration, death and decay. Zooplankton populations affect dissolved oxygen concentrations through the consumption of phytoplankton, respiration, death and decay. Their populations fluctuate with water temperature, hydrodynamic conditions, phytoplankton abundance, and other factors. Due to the influence of these organisms on dissolved oxygen concentrations it may be important to include zooplankton population dynamics in the simulation of dissolved oxygen in the Lower San Joaquin River.

The objective of subtask 5.6 was to incorporate numerical code that describes zooplankton grazing and distribution into the existing Link-Node TMDL model. Zooplankton concentrations vary greatly in different sections of the river, so the zooplankton simulation algorithms and modeling architecture were designed so that coefficients affecting the zooplankton population dynamics can be changed for each node within the model domain.

Methods

The simulation of zooplankton population dynamics has been incorporated into the San Joaquin Estuary Link-Node model . Model input files were altered to incorporate the parameters relevant to zooplankton modeling, and the following equations were added to the Link-Node model in order to simulate zooplankton population dynamics. The equations were adopted from *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition)* (USEPA,1985). The change in zooplankton concentration is calculated as:

$$\frac{dz}{dt} = (G_z - R_z - M_z)Z$$

where: $\frac{dz}{dt}$ = the change in zooplankton concentration with respect to time, mg/L/time

G_z = the gross growth rate of zooplankton, 1/time

R_z = the zooplankton respiration and excretion rate, 1/time

M_z = the zooplankton mortality rate, 1/time
Z = the zooplankton concentration, mg/L

The growth rate of zooplankton is calculated as:

$$G_z = g_z^{20}\theta_g^{(T-20)}\left(\frac{F_T}{K_z + F_T}\right)$$

where: g_z^{20} = the zooplankton growth rate at 20° Celsius
θ_g = temperature coefficient for zooplankton growth, unitless
T = temperature, degrees Celsius
F_T = phytoplankton concentration, mg/L
K_z = Half-saturation constant of zooplankton growth, mg/L

The respiration rate of zooplankton is calculated as:

$$R_z = r_z^{20}\theta_r^{(T-20)}$$

where: r_z^{20} = zooplankton respiration rate at 20° Celsius
θ_r = temperature coefficient for zooplankton respiration, unitless
T = temperature, degrees Celsius

The mortality of zooplankton is calculated as:

$$M_z = m_z^{20}\theta_m^{(T-20)}$$

where: m_z^{20} = zooplankton mortality rate at 20° Celsius
θ_m = temperature coefficient for zooplankton mortality, unitless
T = temperature, degrees Celsius

The range of acceptable values for g_z^{20}, r_z^{20}, and m_z^{20} can be defined based on the range of literature values provided in the USEPA Rates, Constants, and Kinetics Formulations document. The ranges of acceptable values are 0.1-0.3 day^{-1}, 0.01-0.20 day^{-1}, and 0.015-0.075 day^{-1} for g_z^{20}, r_z^{20}, and m_z^{20} respectively. θ_g, θ_r, and θ_m are used to describe the amplitude of the dependence of water temperature on zooplankton growth, respiration, and mortality. These parameters could be used in conjunction with the growth, respiration, and mortality rates to calibrate the Link-Node model to seasonal variance in measured zooplankton populations.

Results and Discussion

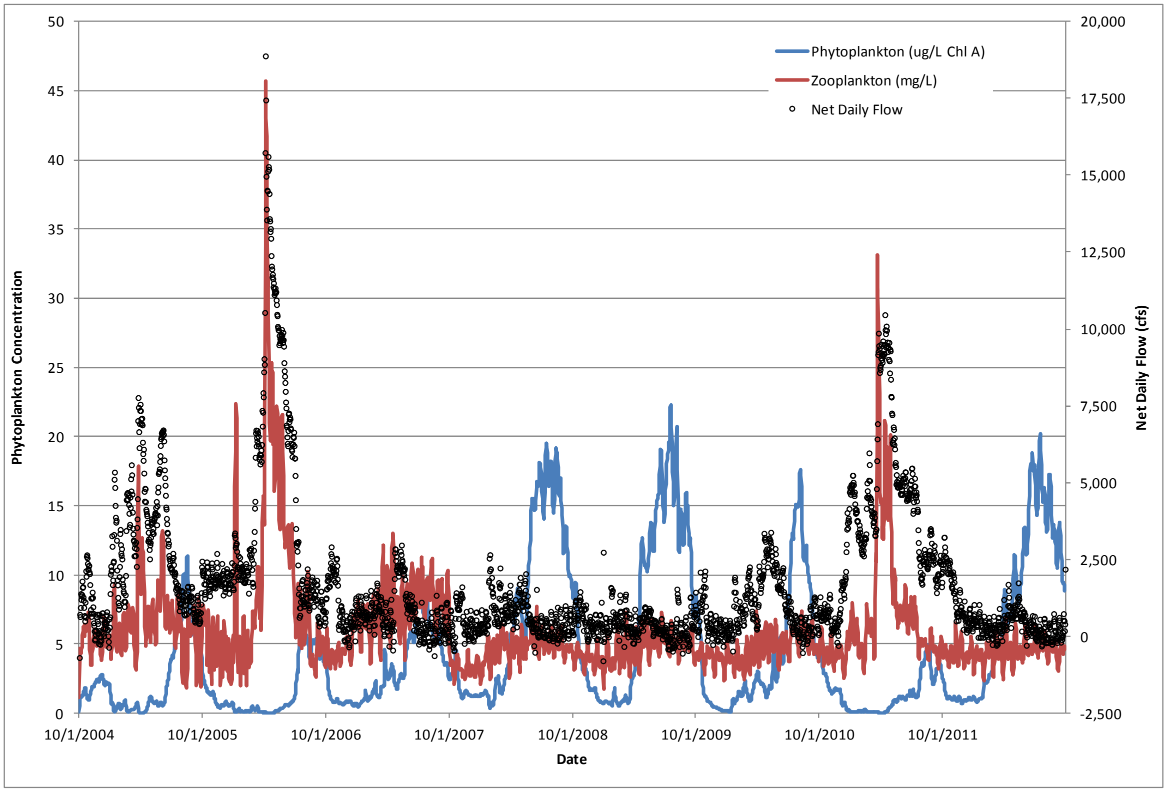

Figure Figure 1 and Figure 2 illustrate Link-Node simulated phytoplankton, simulated zooplankton, and measured net daily river discharge results at Rough and Ready Island and Garwood Bridge respectively. The Link-Node model has not been calibrated to measured data for either phytoplankton or zooplankton, so the results may or may not be representative of actual concentrations at either location. The figures illustrate the interdependency of phytoplankton and zooplankton. An increase in phytoplankton populations provides an abundant food source for zooplankton communities, and is consequently followed by an increase in the concentration of zooplankton. When zooplankton populations become abundant, phytoplankton populations decline as a result of increased predation. The decline in phytoplankton results in a food shortage for the zooplankton, and zooplankton populations decrease. In the absence of high predator concentrations the phytoplankton population will begin to increase, repeating the cycle. The predator-prey relationship between zooplankton and phytoplankton is influenced by the time of year and the hydrodynamics as well. Phytoplankton concentrations tend to increase over the course of the spring and summer, then decrease as water temperatures decrease through the fall.

The comparison between the Garwood Bridge and RRI results illustrates that high net river discharge affects phytoplankton and zooplankton concentrations by transporting zooplankton communities downstream. It appears that with the model's current parameterization, the region of the San Joaquin river located between the DWSC and the upstream model domain boundary is serving as a nursery water for zooplankton. Zooplankton populations thrive in the region due to an abundant supply of phytoplankton from upstream sources. The zooplankton are occasionally transported downstream into the DWSC during flood events. The magnitude of both zooplankton and phytoplankton populations, and the interaction between the populations can be altered through calibration of the model to measured data if/when a comprehensive dataset is available.

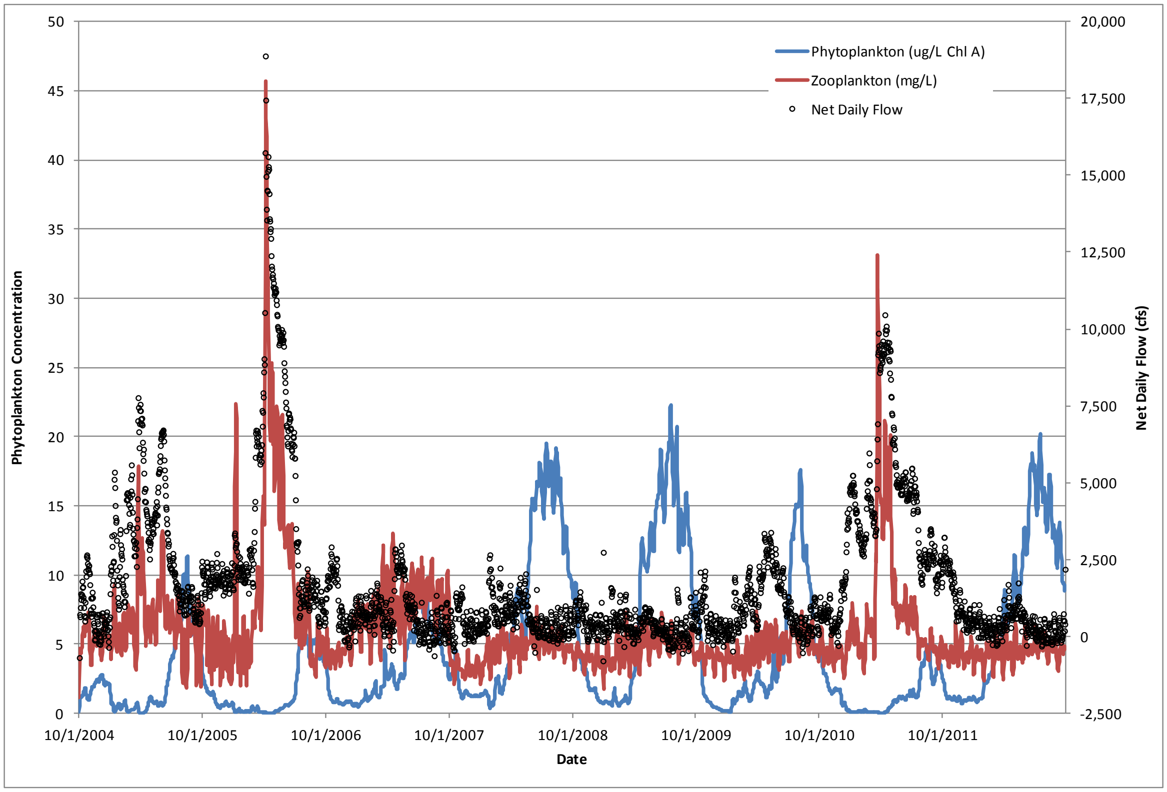

Figure 1 Simulated phytoplankton and zooplankton concentrations at Rough and Ready Island, October 2004 through September 2012

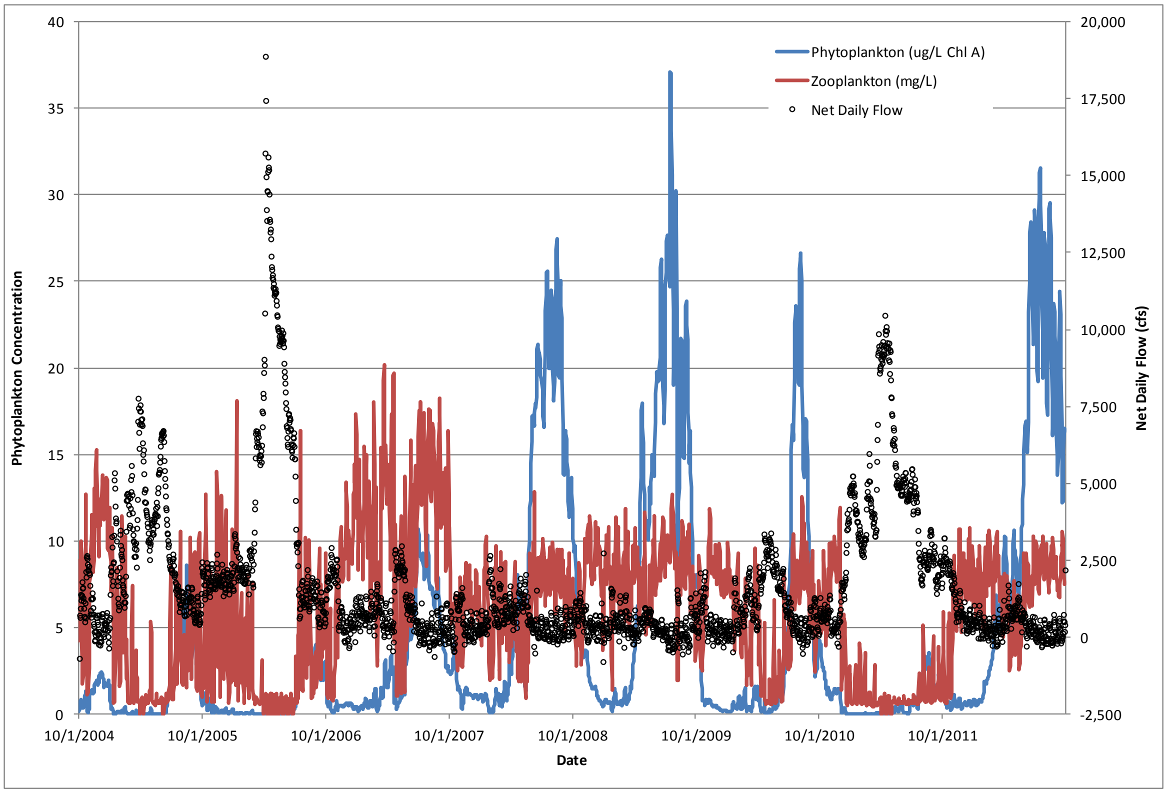

Figure 2 Net river discharge, phytoplankton concentration and zooplankton concentration in the San Joaquin River at Garwood Bridge, October 2004 through September 2012

In order to calibrate the zooplankton model, observed zooplankton population data could be used to refine estimates of the zooplankton growth, respiration and mortality rates. As outlined in the methods section of this report, the USEPA Rates, Constants, and Kinetics Formulations document provides ranges of acceptable values for these parameters. The ranges are broad because the equations are formulated to simulate the zooplankton community instead of individual zooplankton species. Each zooplankton species will have optimal conditions for growth, respiration, and death. Therefore, appropriate rates for a community comprised of multiple zooplankton species will vary depending on the community composition.

Collection and analysis of zooplankton data in the lower San Joaquin River can be used to facilitate the Link-Node zooplankton model calibration. Measurement of San Joaquin River zooplankton community species composition and growth, respiration and death rates would help to constrain the acceptable range for these parameters within the Link-Node model. The Link-Node model is capable of simulating both the temporal and spatial variation in zooplankton populations. In order to calibrate the model in both the temporal and spatial dimensions, a dataset consisting of depth-integrated (Link-Node provides depth integrated concentration as output) zooplankton population measurements made at multiple locations will be required. Weekly, bi-weekly, or monthly sample collection at each location will make it possible to calibrate the model to simulate temporal trends in zooplankton abundance. The selected interval for sample collection will be determined by available budget and human resources, though trends in zooplankton population dynamics may be missed by coarse temporal resolution sampling strategies.

Conclusion

The objective of task 5.6 has been met through the incorporation of zooplankton population dynamics algorithms into the Link-Node model of the tidal portion of the San Joaquin River. The updated model is capable of simulating zooplankton growth, respiration, mortality, and the effect of zooplankton on phytoplankton populations at all locations within the model domain.

Acknowledgements

We gratefully acknowledge the Ecosystem Restoration Program and its implementing agencies (California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and the National Marine Fisheries Service) for supporting this project (E0883006, ERP-08D-SO3).